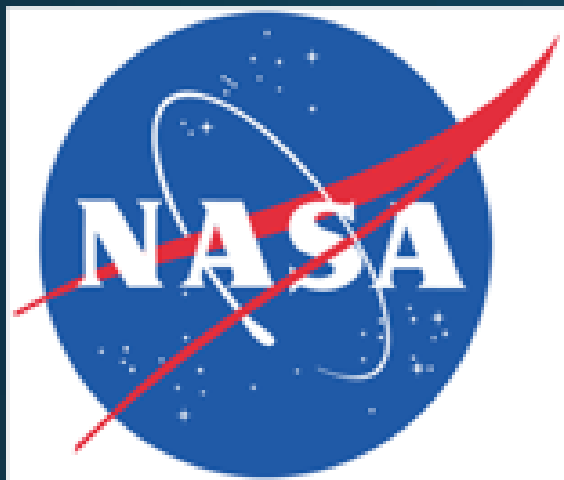# Integrating Space-Borne Lightning Characteristics and Ground-Based Metrics for Assessing Thunderstorm Intensity

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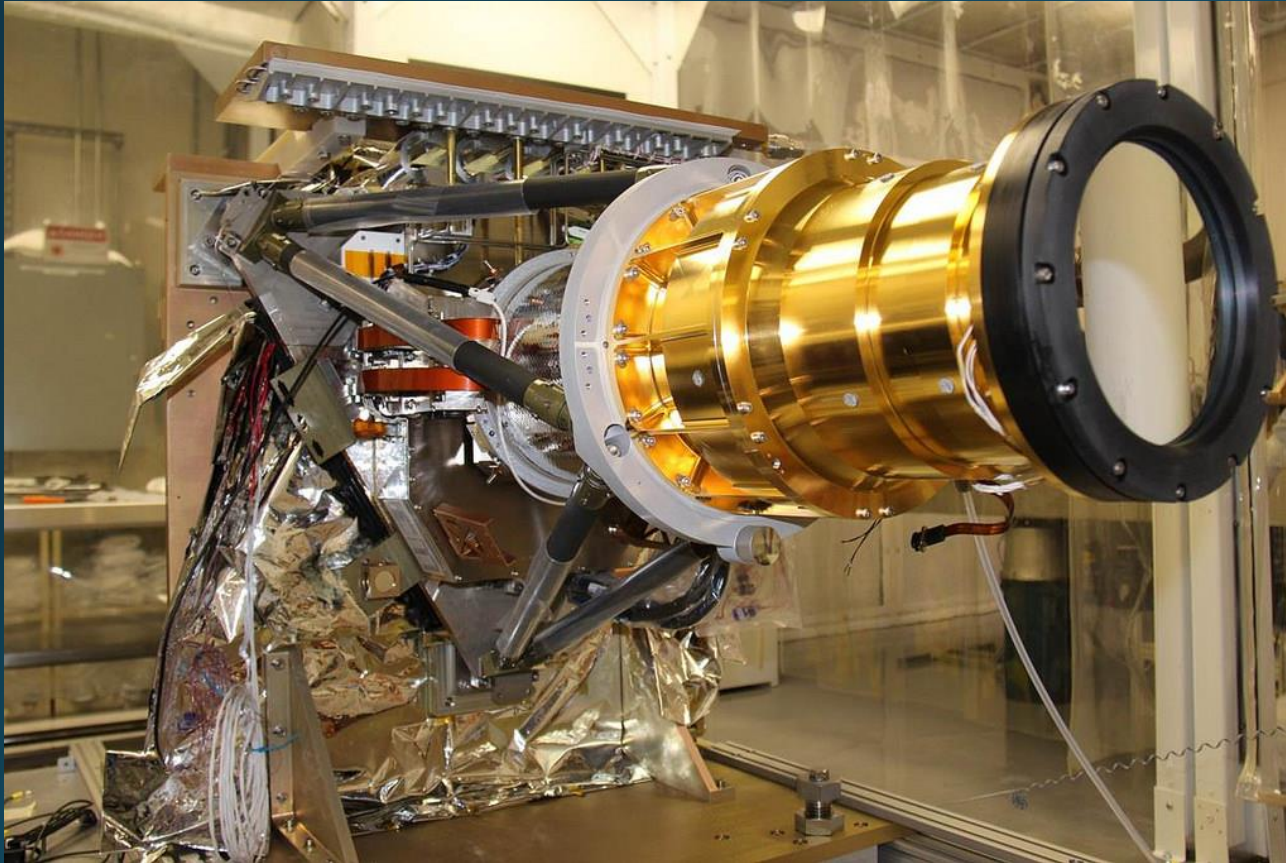
Motivation

Image of the Geostationary Lightning Mapper, courtesy of www.goes-r.gov

- How do Geostationary Lightning Mapper observations align with ground based relationships between lightning and storm intensity?

- What are some of the characteristics of sub-flash properties in a variety of storms?

GOAL: take a first glance of well characterized storms to determine how GLM properties can enhance thunderstorm intensity measurements.
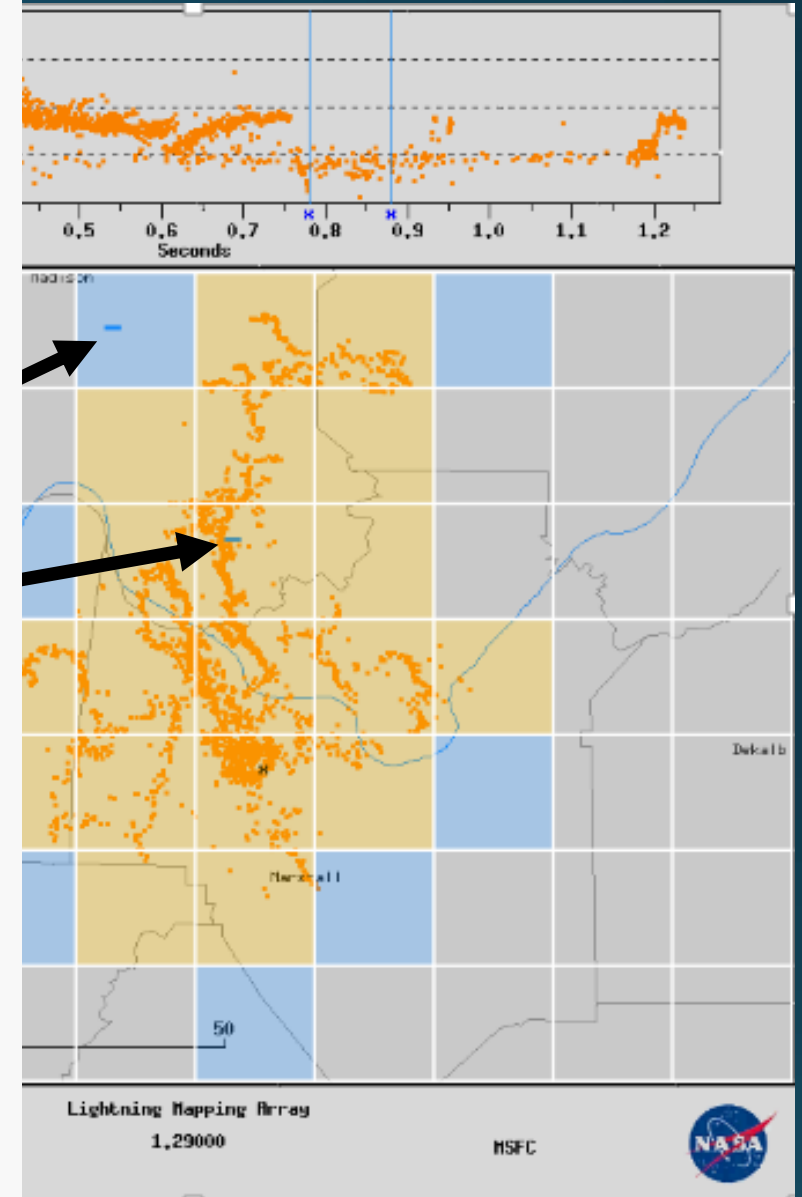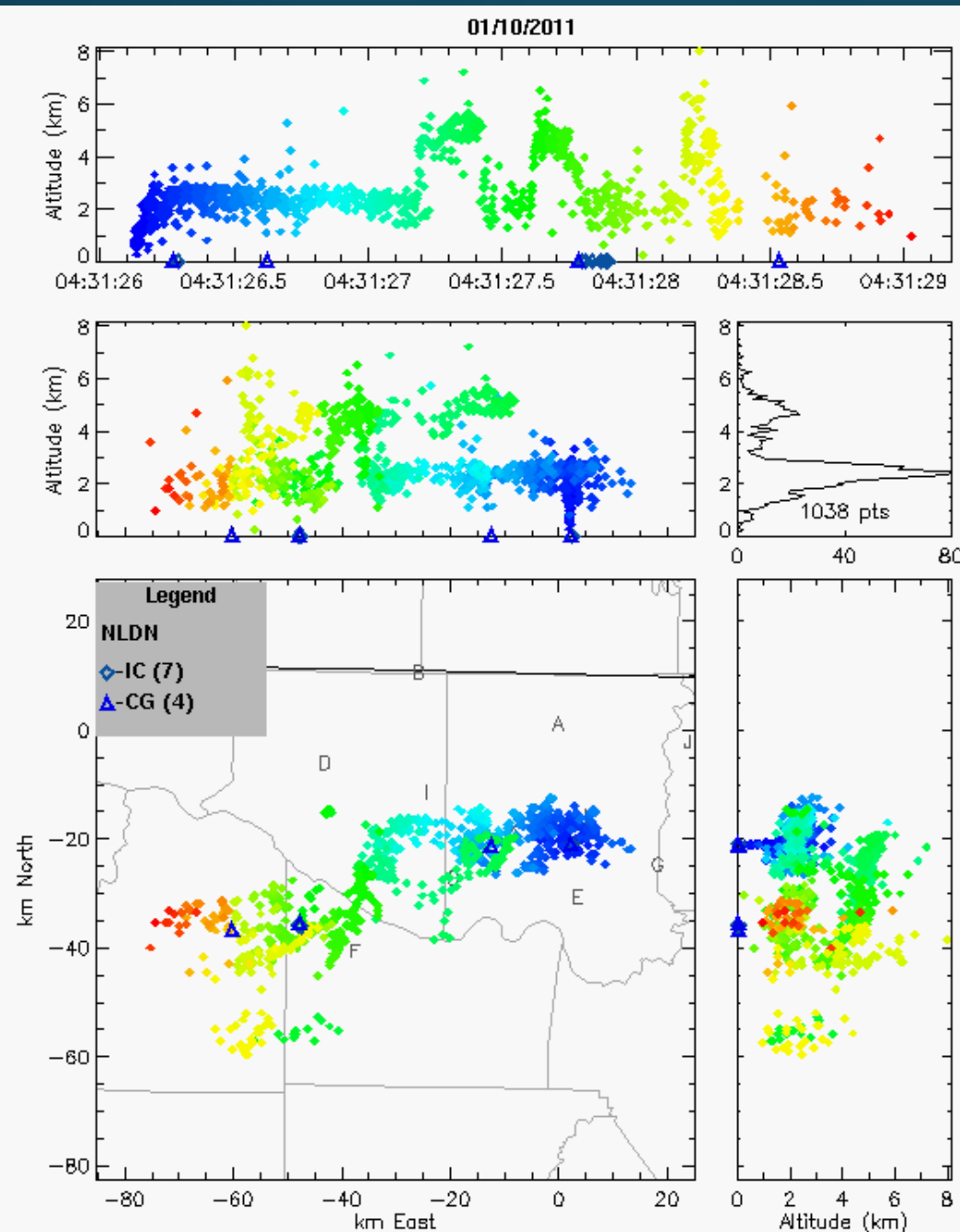
Why ground networks

Lightning Mapping Arrays
- limited in range (~150 domain center). A
- Detect different parts of lightning flash.

LF/VLF (e.g., National Li Detection Network and Ea Networks)
- have larger domains
- detect fewer flashes/str LMA or TRMM-LIS
    - Bitzer et al. 2016, J
- No spatial component.

and NLDN (minus signs) overlaid for a single flash
Schultz et al. (2017), J. Operational Meteorology, in review

The Temporary Solution

- The best spaceborne lightning data is from the Tropical Rainfall Measuring Mission-Lightning Instrument Sensor (TRMM-LIS; Kummerow et al. 1998, Christian et al. 2000)

  - Limited temporal observations at a single location.

  - Lightning measurements very similar to GOES-16's GLM.
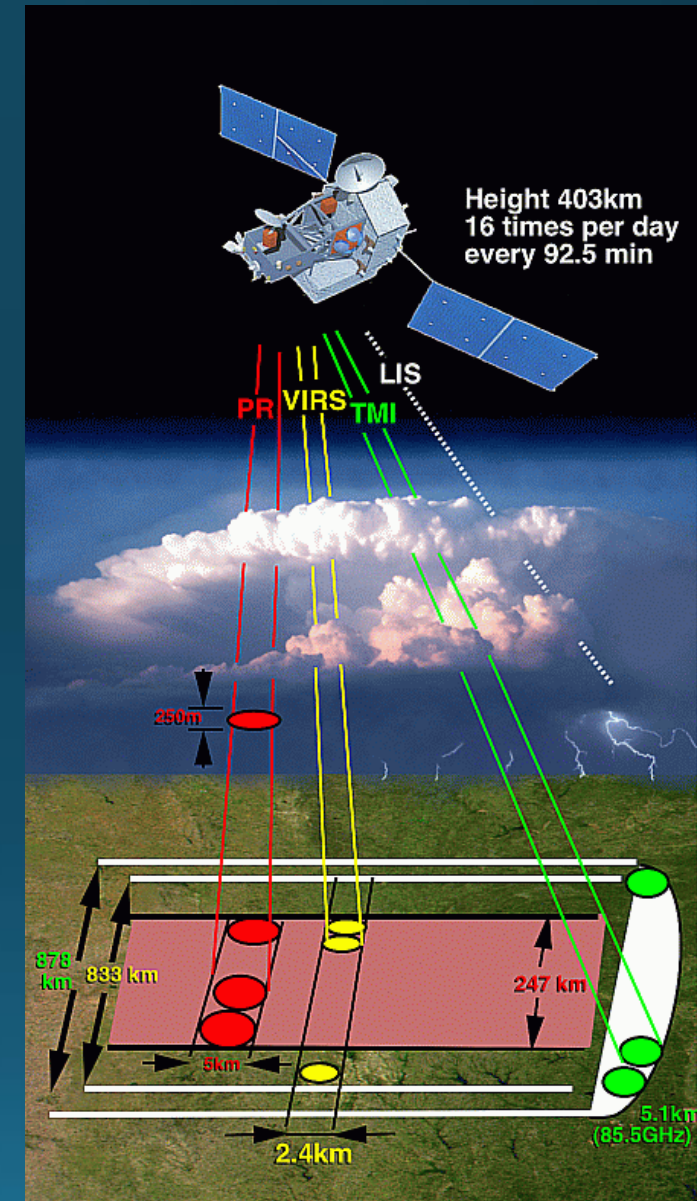
Data for Analysis

- Lightning data
  - Tropical Rainfall Measuring Mission (Kummerow et al. 1998)
    - Lightning Imaging Sensor (Christian et al. 2000)
  - North Alabama Lightning Mapping Array (NALMA)
   - Rison et al. 1999, Koshak et al. 2004

- Weather Service Radar, 88D (NEXRAD) radar information
  - Crum and Alberty (1993), Parks et al. (2009)
 - Horizontal reflectivity (Z), maximum expected size of hail (MESH)

Methods

- 68 TRMM overpasses that were coincident with a 1500 thunderstorm database in Schultz (2015).
  - Data range 2002-2012

- These storms contained:
  - Location (time, latitude, longitude)
  - LMA flash rate
  - Reflectivity profile from NEXRAD
  - Maximum expected size of hail
  - Severity information

- Normalized flash rate based on satellite overpass duration.

- Used Conditional Probability Metrics to quantify utility in identifying severe thunderstorms.

Blue box represents time of TRMM overpass

Radar Reflectivity

Updraft Volume vs Flash Rate
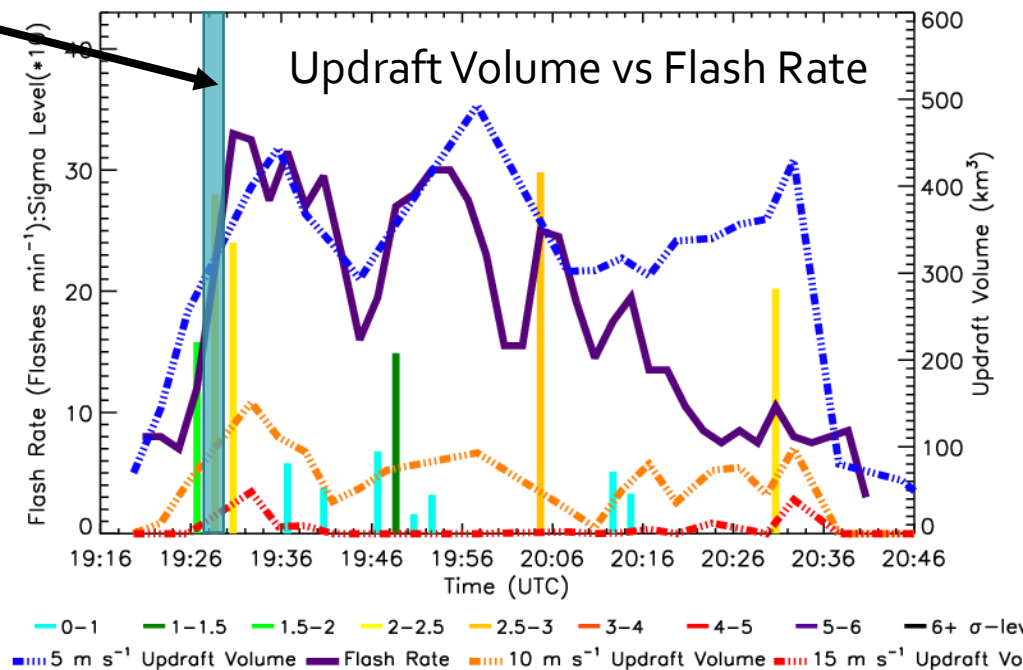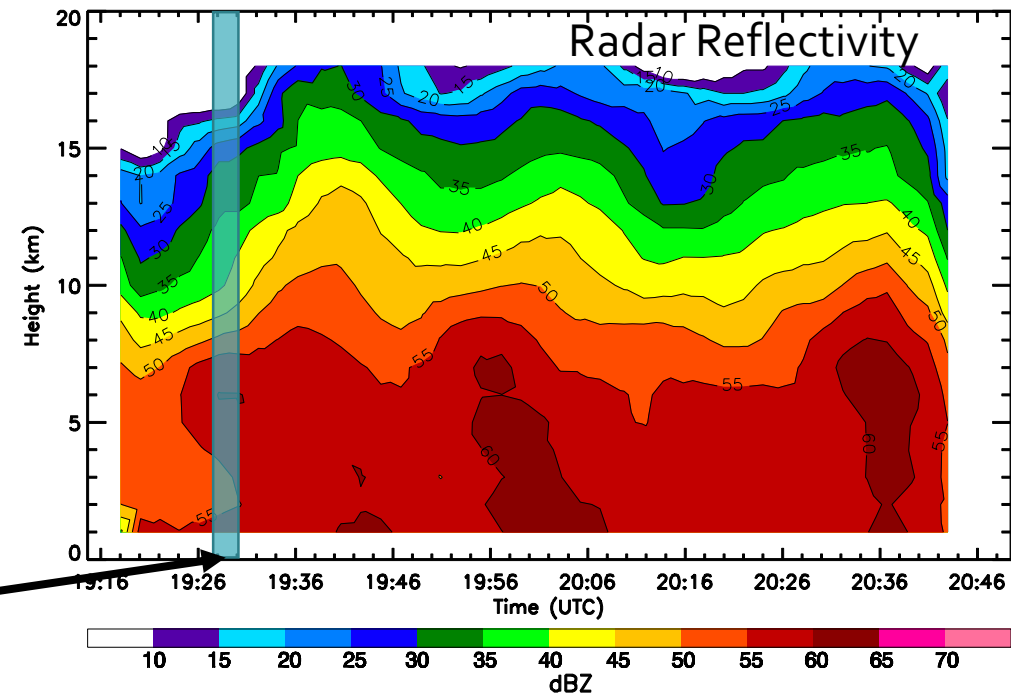
LMA Flash Rate vs TRMM Flash Rate
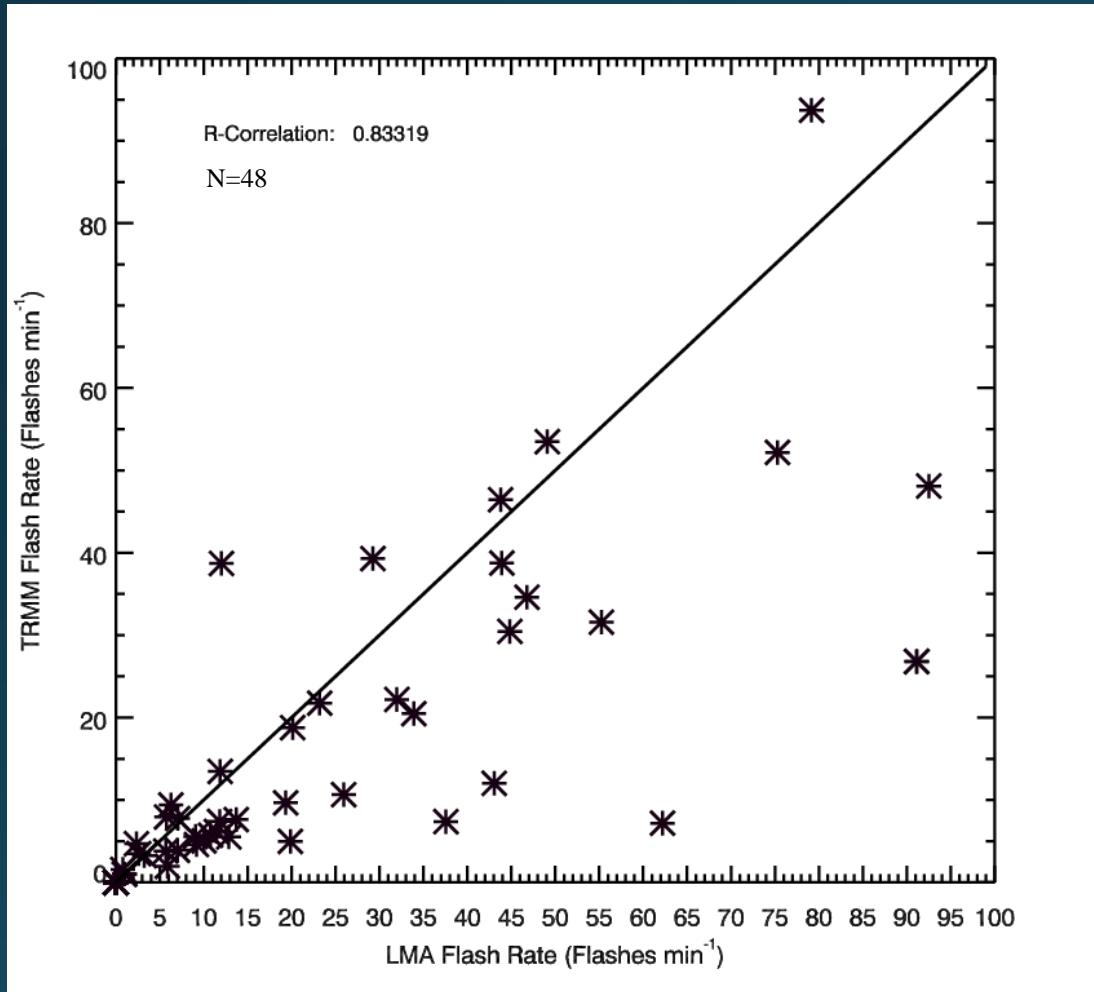
- **Strong correlation between LMA flash rate and TRMM-LIS flash rate.**
  - R=0.88, not using zero flash storms.

- **Range from LMA and small parallax offsets have not been accounted for yet.**
  - Tracking at 6-7 km, TRMM-LIS assumes 13 km height.

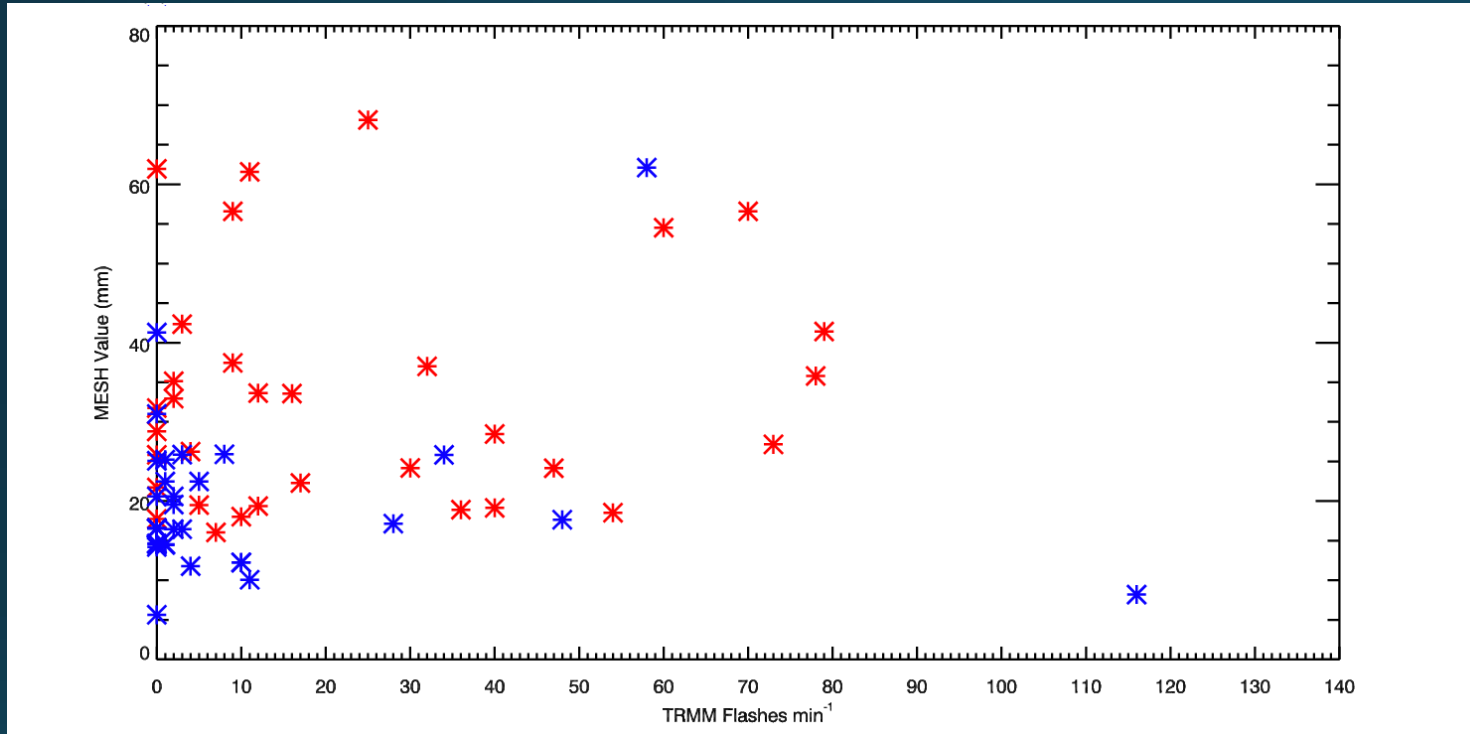# Reflectivity Profile of Thunderstorms vs TRMM-LIS Flash Rate

- As expected, different reflectivity profiles produce different flash rates.

- For the most part, LMA flash rates are higher than TRMM-LIS flash rates.

- Useful though to see how the order of "intensity" changes with different flash properties.
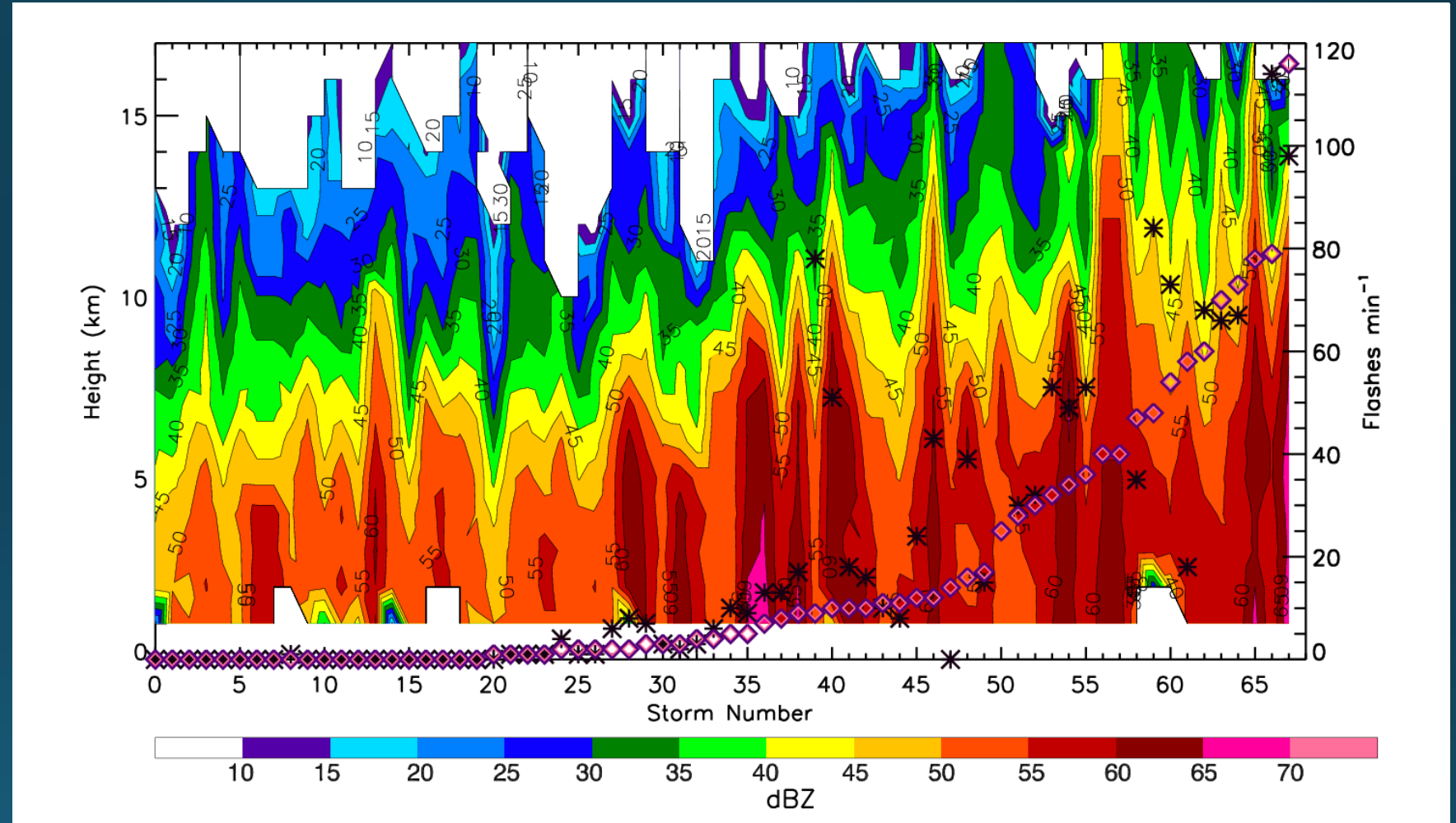
Less Intense ← → More Intense

MESH and TRMM Flash Rate

- Chronis et al. (2015) demonstrated that storms with lightning jumps and higher flash rates had larger MESH values.

- Schultz et al. (2016) showed that combining storms with MESH and lightning jumps objectively identified severe storms better than MESH alone.
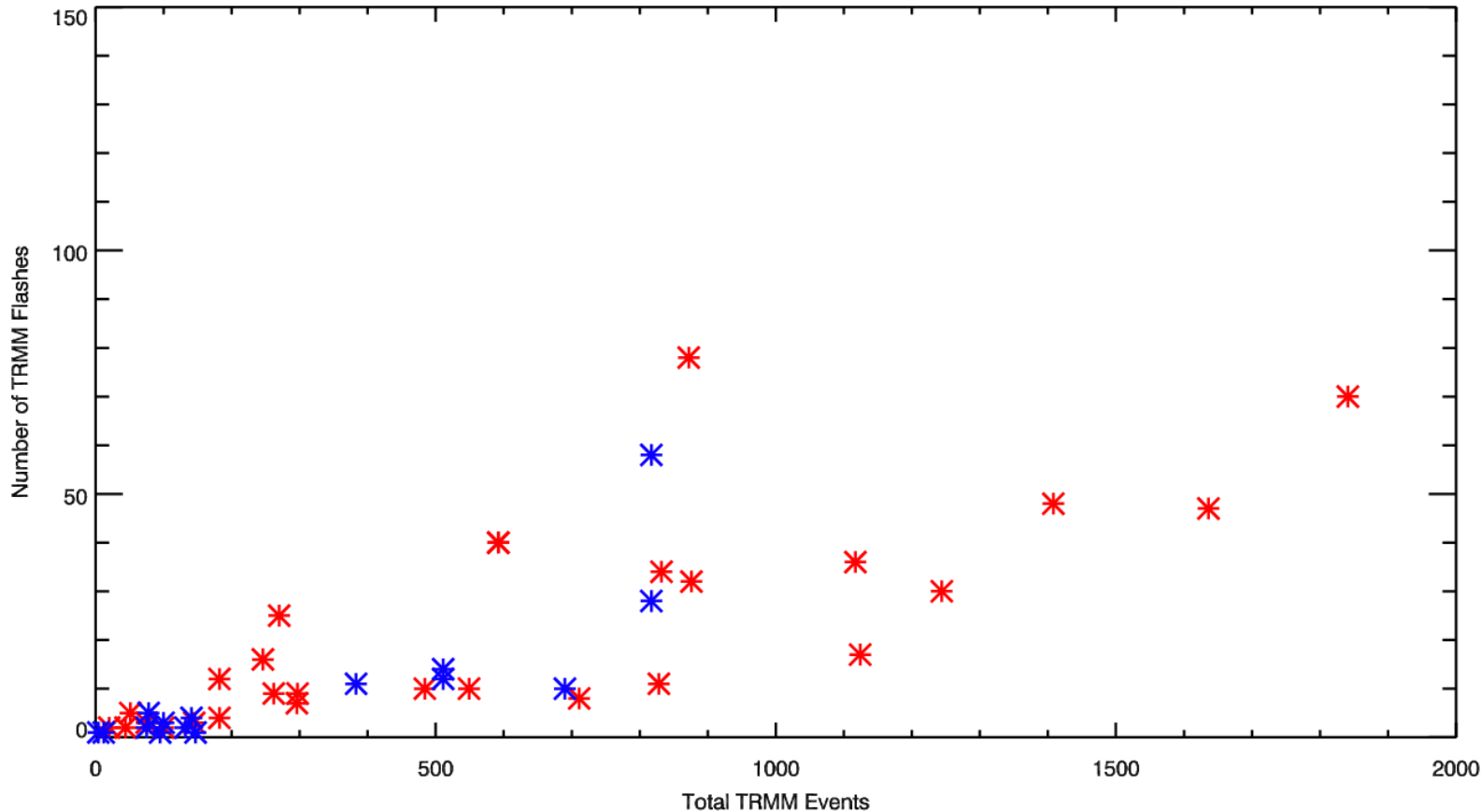
Conditional Probability of a storm being identified as severe:

MESH Alone (MESH$\geq$ 25.4 mm): 48.6% (18/37)   Flash Rate $\geq$10 flash min^{-1}: 69.6% (16/23)

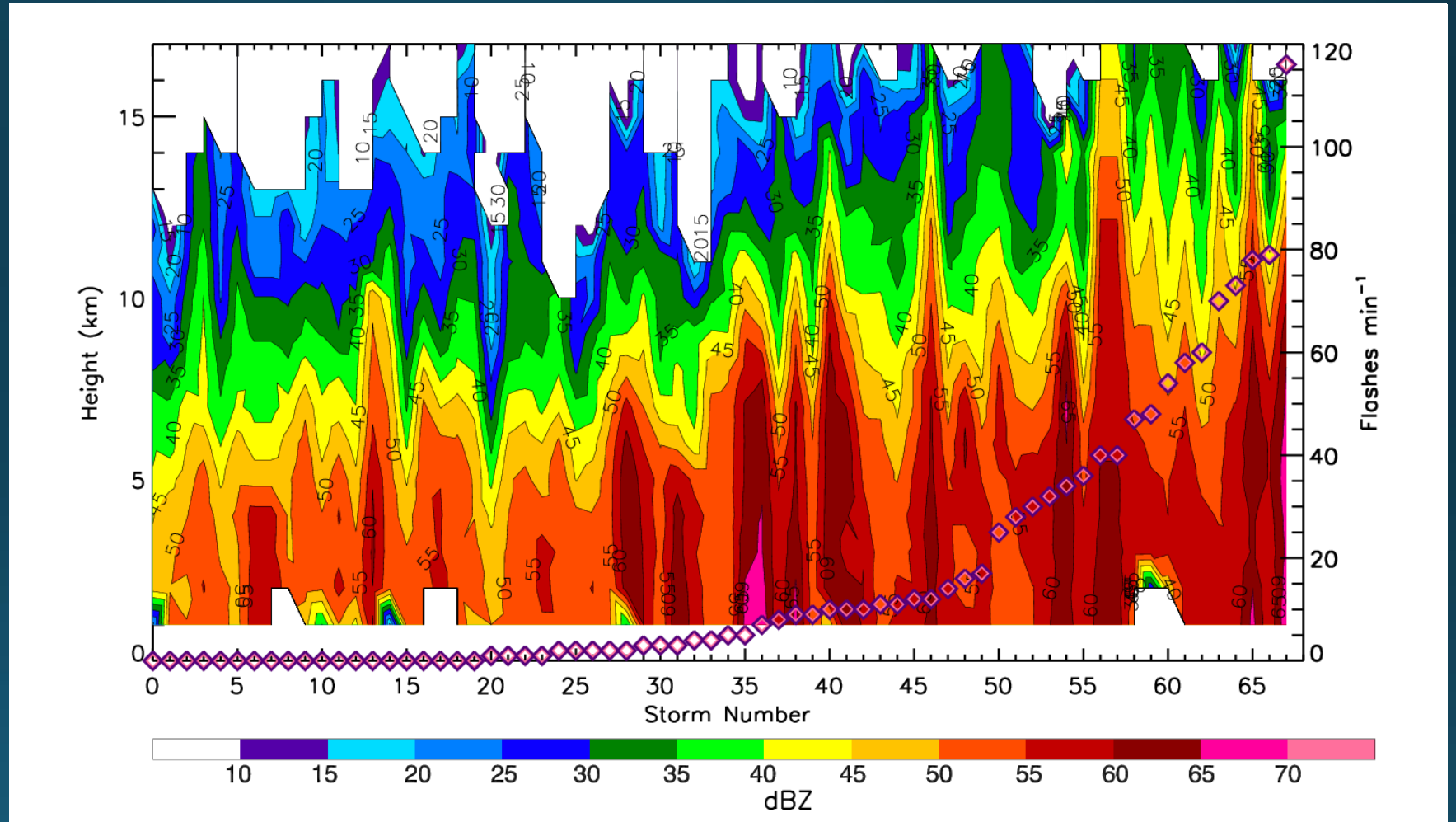Flash Rate $\leq$10 flash min^{-1}: 40.0% (18/45)

What are the range of LIS event rates?

- More flashes should result in higher event rates.

- R-correlation with number of flashes is strong
  - R=0.93

Reflectivity Profile of Thunderstorms vs TRMM-LIS Event Rate
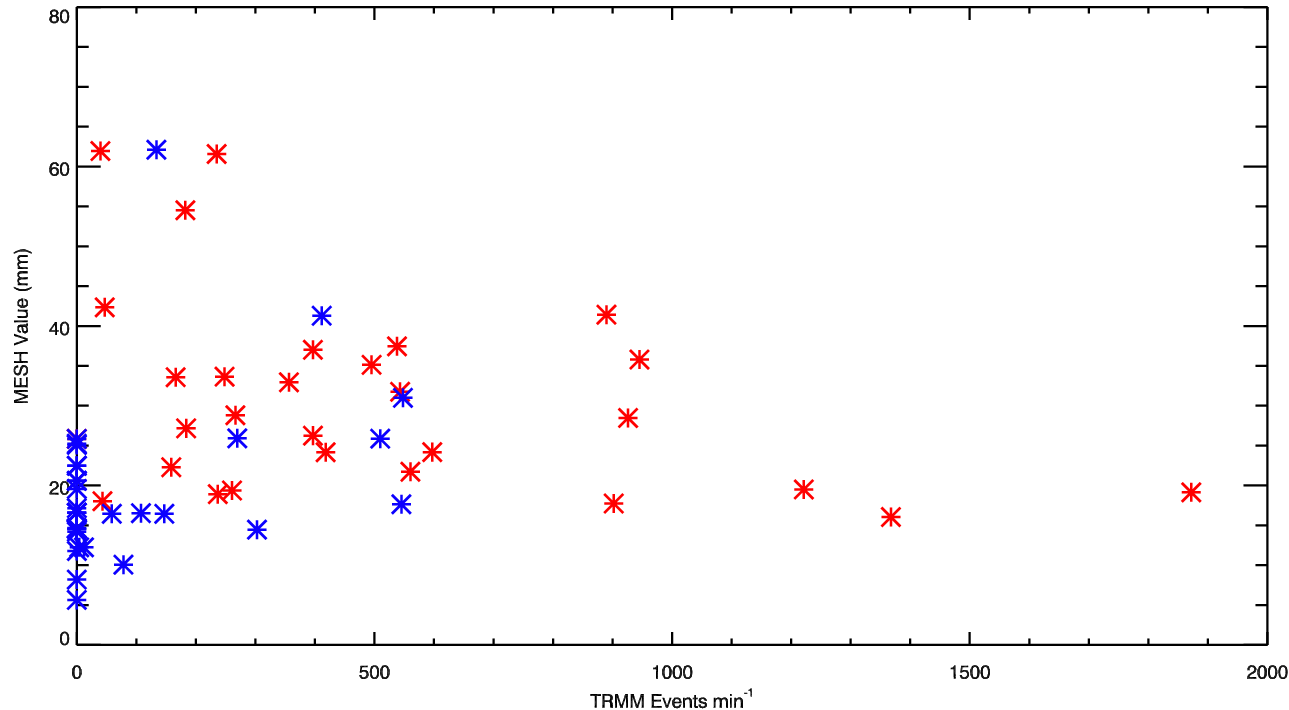
- Slight differences in reflectivity profiles if the event rate is chosen as the intensity metric instead of flash rate.

Less Intense   More Intense

MESH and TRMM event rates

- Highest event rates don't necessarily correspond to the strongest mesh values.

- Seem to separate severe from non-severe in this limited sample.
  - Conditional probabilities slightly higher than using flash rates.

Conditional Probability of a storm being identified as severe:
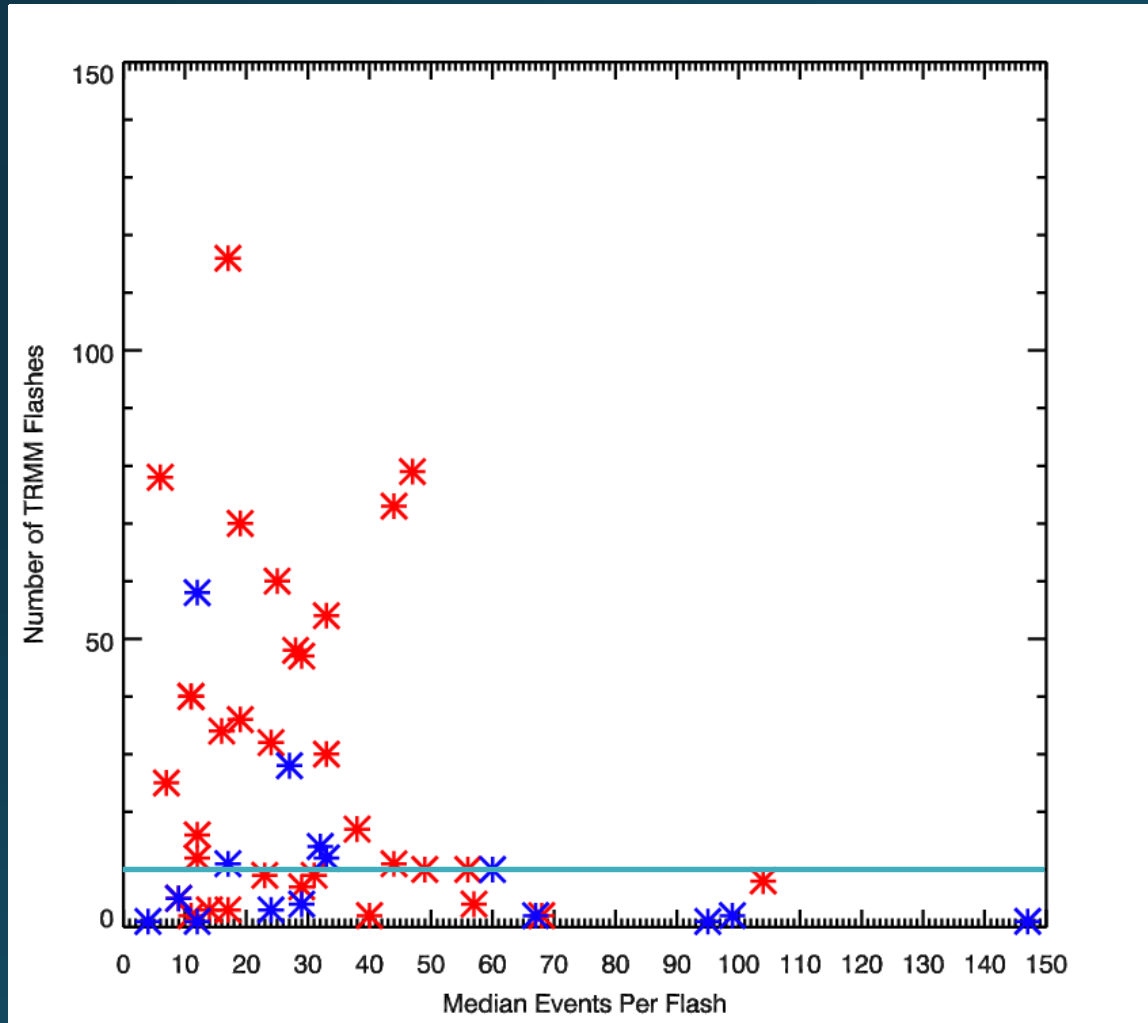
MESH Alone (MESH≥ 25.4 mm): 48.6% (18/37)

Events Alone (≥100 events min⁻¹): 76.9% (30/39)
Events Alone (≥200 events min⁻¹): 73.5% (25/24)

Events Alone (≤100 events min⁻¹): 13.7% (4/29)
Events Alone (≤200 events min⁻¹): 17.5% (6/34)

TRMM Flash Rate vs Events per Flash

- Flash rates > 20 flashes min^{-1} tend to have fewer than 50 events per flash.

- Probability of severity increased in this sample as flash rate increased and events per flash decreased.
  - 25 of 34 severe storms reached 10 flash min^{-1} threshold for 2σ lightning jump algorithm.
  - 6 of 34 non-severe reached this flash rate threshold.

Evidence of Flash Rate vs Flash Size Relationships?

- Increasing flash rate results in a decrease in flash size.
  - Bruning and MacGorman (2013)
  - Calhoun et al. (2013)
  - Schultz et al. (2015, 2017)
- Provides an idea of kinematic texture (i.e., updraft location, turbulence).
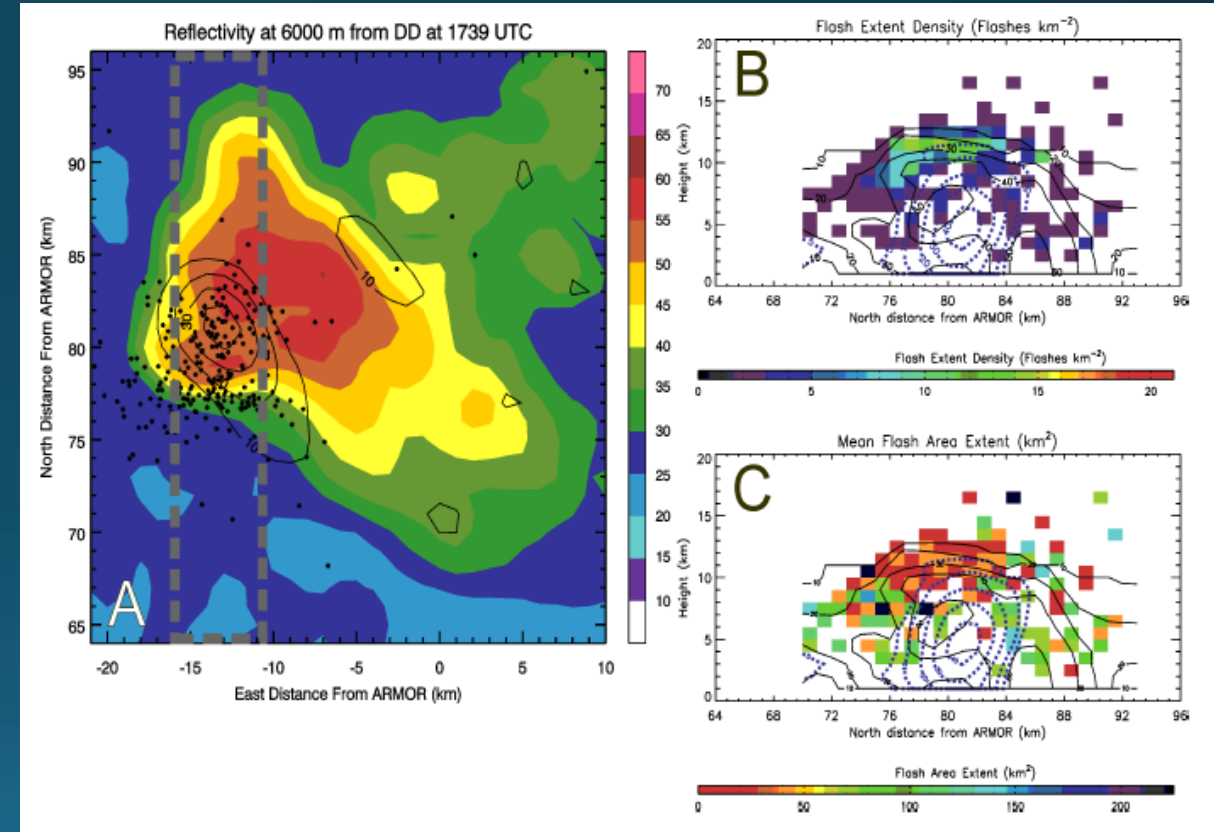
Schultz et al. (2017), WAF, EOR

Discussion/Conclusions

- TRMM flash rates are in good correlation with the LMA flash rates.

- Flash rate and intensity metrics to extend to the satellite realm.

- Event rates and events per flash show additional promise of helping discern storm intensity.
  - Highest conditional probabilities for severe identification was with events, followed by flashes, then MESH alone.

- This work did not incorporate any lightning jump information.
  - Have to wait for GLM data to examine how to alter the current lightning jump algorithm.
  - Important because the jump provides the lead time on peak intensity (Schultz et al. 2009, 2011, 2015, 2016).

- Plan to also incorporate flash energy information into the algorithm.